

UNIVERSIDADE FEDERAL DE SERGIPE
PROGRAMA DE PÓS-GRADUAÇÃO EM ODONTOLOGIA

**LIMITES DE PERCEPTIBILIDADE E ACEITABILIDADE DAS
ALTERAÇÕES DE COR CAUSADAS PELA REDUÇÃO NA
ESPESSURA DO COMPÓSITO CORRESPONDENTE À DENTINA**

Aracaju, SE
Agosto de 2018

SHEILA MARA MORAIS SANTOS

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Dissertação apresentada ao Programa de Pós-Graduação em Odontologia da Universidade Federal de Sergipe, para obtenção do título de Mestre em Odontologia.

Orientador: Prof. Dr. André Luis Faria e Silva

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RESUMO

Este estudo teve como objetivo determinar o limiar de redução na espessura do compósito de cor da dentina necessário para resultar em mudanças de cor perceptíveis e aceitáveis em restaurações simuladas. Três sistemas de compósitos (Charisma Diamond, IPS Empress Direct e Filtek Z350 XT) foram avaliados utilizando corpos de prova cilíndricos construídos com tons de dentina e esmalte. A opacidade dos compósitos foi avaliada usando cilindros de 1,0 mm de espessura sobre fundo preto e branco. Uma cor inicial foi estabelecida para cada sistema pela combinação de esmalte de 1,0 mm de espessura com 3,0 mm de cilindros de resina na cor de dentina sobre um fundo escuro ($n = 9$). Em seguida, foram calculadas as alterações de cor (ΔE_{00}) causadas por reduções sequenciais de 0,1 mm nos cilindros de resina na cor de dentina. Mudanças de opacidade em cilindros na cor de dentina e cilindros combinados de esmalte e dentina foram também avaliadas após cada redução de espessura. Regressão polinomial foi realizada com médias de ΔE_{00} em função da espessura dos cilindros na cor de dentina; e os limiares de aceitabilidade ($\Delta E = 1.77$) e perceptibilidade ($\Delta E = 0.81$) foram calculados. Regressões lineares também foram realizadas para ΔE_{00} em função da opacidade dos cilindros na cor de dentina e do par combinado de cilindros de esmalte-dentina. Com exceção da Charisma, os tons de esmalte apresentaram menor opacidade do que a dentina. Alterações de cor aceitáveis foram observadas nos cilindros na cor de dentina mais finos que foram utilizados 2,0-2,4 mm e 1,1-1,4 mm, respectivamente. Nenhuma diferença entre os sistemas compostos foi observada. Em conclusão, as reduções do compósito da cor da dentina inferiores a 0,6 mm e 1,6 mm não resultaram em alterações perceptíveis e clinicamente relevantes, respectivamente, na cor final das restaurações simuladas.

Descritores: Cor; Resina composta; Estética dental; Fenômenos Ópticos

ABSTRACT

This study aimed to determine the reduction threshold on thickness of dentin shade composite necessary to result in perceptible and acceptable color changes on simulated restorations. Three composite systems (Charisma Diamond, IPS Empress Direct, and Filtek Z350 XT) were evaluated using cylinder-shaped specimens built-up with dentin and enamel shades. Opacity of the composites was assessed using 1.0 mm thick specimens over black and white backgrounds. A baseline color was established for each system by combining 1.0 mm thick enamel shade with 3.0 mm of dentin shade cylinders over a dark background ($n = 9$). Then, the color changes (ΔE_{00}) caused by sequential 0.1 mm reductions on dentin shade cylinders were calculated. Opacity changes on dentin shade cylinders and combined enamel-dentin pair cylinders were also assessed after each thickness reduction. Polynomial regression was performed with averages of ΔE_{00} as function of thickness of dentin shade cylinders; and acceptability ($\Delta E = 1.77$) and perceptibility ($\Delta E = 0.81$) thresholds were calculated. Linear regressions were also performed for ΔE_{00} as function of opacity of dentin shade cylinders and combined enamel-dentin pair of cylinders. Except for Charisma, enamel shades presented lowest opacity than dentin one. Perceptible and acceptable color changes were observed for dentin shade cylinders thinner than 2.0-2.4 mm and 1.1-1.4 mm, respectively, were used. No difference among the composite systems were observed. In conclusion, reductions of dentin shade composite lower than 0.6-mm and 1.6-mm did not result in perceptible and clinically relevant changes, respectively, on ultimate color of simulated restorations.

Descriptors: Color; Composite dental resin; Esthetics, Dental; Optical phenomena.

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1 INTRODUÇÃO

Restaurações diretas de resina composta em dentes anteriores constituem-se como uma excelente opção para resolver problemas estéticos envolvendo significativa descoloração e/ou alteração na forma dos dentes, ou para fechar diastemas (1-3). Além do fácil manuseio, os sistemas compósitos disponíveis apresentam variações de cores e graus de translucidez que permitem mimetizar o esmalte e a dentina da estrutura dental (4,5). Quando comparadas às cerâmicas, as resinas compostas apresentam reduzido custo, permitindo sua indicação mesmo para pacientes com menor poder aquisitivo (6). Entretanto, a habilidade e o conhecimento dos clínicos em relação aos aspectos estéticos do sorriso, características ópticas dos tecidos duros dentais e dos compósitos são essenciais para alcançar restaurações diretas esteticamente adequadas.

Dentre os parâmetros importantes para obtenção de estética na odontologia, a obtenção de semelhança de cor entre o material restaurador e a estrutura dentária é fundamental (7). A cor da estrutura dental é determinada pela interação entre as propriedades ópticas do esmalte e da dentina, que apresentam características intrínsecas distintas que afetam o comportamento óptico de cada estrutura, sendo a cor final determinada pela interação dos fenômenos de dispersão, refração, transmissão e absorção da luz incidida (8). Assim, o grau de translucidez das estruturas dentárias, definida como a capacidade do objeto em permitir a passagem da luz e visualização da estrutura subjacente, tem forte influência na cor final da estrutura (9). O esmalte, um tecido cristalino caracterizado por alto conteúdo mineral, é uma estrutura cromática translúcida e permite a visualização da dentina subjacente, modificando a cor deste tecido e ajudando a definir a cor final do elemento dental (5,10-12). Por outro lado, o maior conteúdo orgânico da dentina aumenta sua opacidade, e a cromaticidade desse tecido afeta fortemente a cor do dente (11,12). Assim, além de apresentarem diferentes cromacidades, os compósitos odontológicos para restaurações estéticas também apresentam diferentes níveis de translucidez que os permitem simular as características ópticas do esmalte e dentina (3,5).

Entretanto, além do grau de translucidez, a espessura do incremento de compósito também afeta a transmissão de luz através do volume do material (10-12). Portanto, o uso de espessuras similares às daquelas dos tecidos duros dentários apenas resultaria em aspectos ópticos similares se a translucidez/ opacidade do compósito fosse semelhante às observadas na dentina e no esmalte dental. No entanto, compósitos com diferentes graus de translucidez/ opacidade estão disponíveis no mercado. Compósitos de cor de esmalte de alguns fabricantes

são mais translúcidos que o esmalte natural, enquanto alguns compósitos de cor da dentina são mais opacos do que a dentina natural, dificultando a estratificação da restauração de compósitos (13,14).

Todos esses detalhes devem ser levados em consideração durante a confecção de restaurações estéticas em resina, pois a mimetização da cor das estruturas dentais é fundamental nestes procedimentos. A ausência de opacidade adequada do compósito pode permitir a visualização de um tecido dentinário muito escurecido, por exemplo, resultando em restaurações com menor valor (variação do preto para o branco) (15). Da mesma forma, a ausência de opacidade adequada em restaurações classe IV permitem a visualização do fundo da cavidade oral, o que tornaria a restauração final acinzentada (16, 17). Idealmente, um substrato escurecido deve ser mascarado usando menor espessura possível, permitindo que compósitos menos opacos e mais estéticos, simulando o esmalte, sejam utilizados com maior liberdade como último incremento (18-21). Entretanto, há escassez de estudos avaliando as propriedades ópticas das resinas compostas correspondentes à dentina, com maior opacidade e capacidade de mascaramento, e a sua relação com a cor final das restaurações. Assim, este estudo objetivou determinar as espessuras mínimas de compósitos correspondentes à dentina necessários para evitar alterações de cor perceptíveis e manter diferenças de cor aceitáveis em restaurações simuladas, mantendo constante a espessura do compósito de cor do esmalte, avaliadas sobre um fundo escuro.

2 PROPOSIÇÃO

Objetivo Geral

Determinar as espessuras mínimas de compósitos correspondentes à dentina necessários para evitar alterações de cor perceptíveis e manter diferenças de cor aceitáveis em restaurações simuladas, mantendo constante a espessura do compósito de cor do esmalte, avaliadas sobre um fundo escuro.

3 METODOLOGIA

3.1 Preparo das amostras

Três sistemas de resinas compostas foram avaliados no presente estudo: Charisma Diamond (Heraeus Kulzer, Hanau, Alemanha), IPS Empress Direct (Ivoclar Vivadent, Schaan, Liechtenstein) e Filtek Z350 XT (3M ESPE, St. Paul, MN, EUA). Para cada sistema, foram selecionadas cores com opacidades correspondentes ao esmalte e à dentina. (Tabela 1; Figura 1).

Tabela 1. Compósitos utilizados no estudo.

Sistema de compósito	Fabricante	Cores
Charisma Diamond	Heraeus Kulzer, Hanau, Germany	A1 (esmalte)
		OL (dentina)
IPS Empress Direct	Ivoclar Vivadent, Schaan, Liechtenstein	EA1 (esmalte)
		DA1 (dentina)
Filtek Z350 XT	3M ESPE, St. Paul, MN, USA	A1E (esmalte)
		A1B (dentina)



Figura 1 - Sistemas de resinas compostas. Da esquerda para direita, Charisma Diamond, IPS Empress Direct e Filtek Z350 XT.

Para caracterizar a opacidade das cores da dentina e do esmalte de cada sistema, corpos-de-prova cilíndricos (10 mm de diâmetro x 1,0 mm de espessura) foram construídos pela inserção de compósitos em um molde metálico, preenchido em incremento único (Figura 2). Os compósitos foram fotopolimerizados com um aparelho fotopolimerizador a bade de LED Radii Cal (irradiância $\approx 1.000 \text{ mW/cm}^2$; SDI, Victoria, Austrália) por 40 segundos, seguida do polimento de amostras com lixas de carbeto de sílcio (granuação nº 600), e o diâmetro final foi mensurado com um paquímetro digital.



Figura 2 - Corpo-de-Prova cilíndrico (10 mm de diâmetro x 1,0 mm de espessura)

3.2 Mensuração de opacidade

A opacidade das amostras ($n = 3$) foi avaliada com um espectrofotômetro de esfera (SP60, X-Rite, Grand Rapids, MI, EUA) (Figura 3), em modo de reflectância, usando o sistema do *International Commission on Illumination* CIE Lab, sendo os parâmetros L, a e b, correspondentes aos eixos branco-preto, vermelho-verde e amarelo-azul, respectivamente (Figura 4).

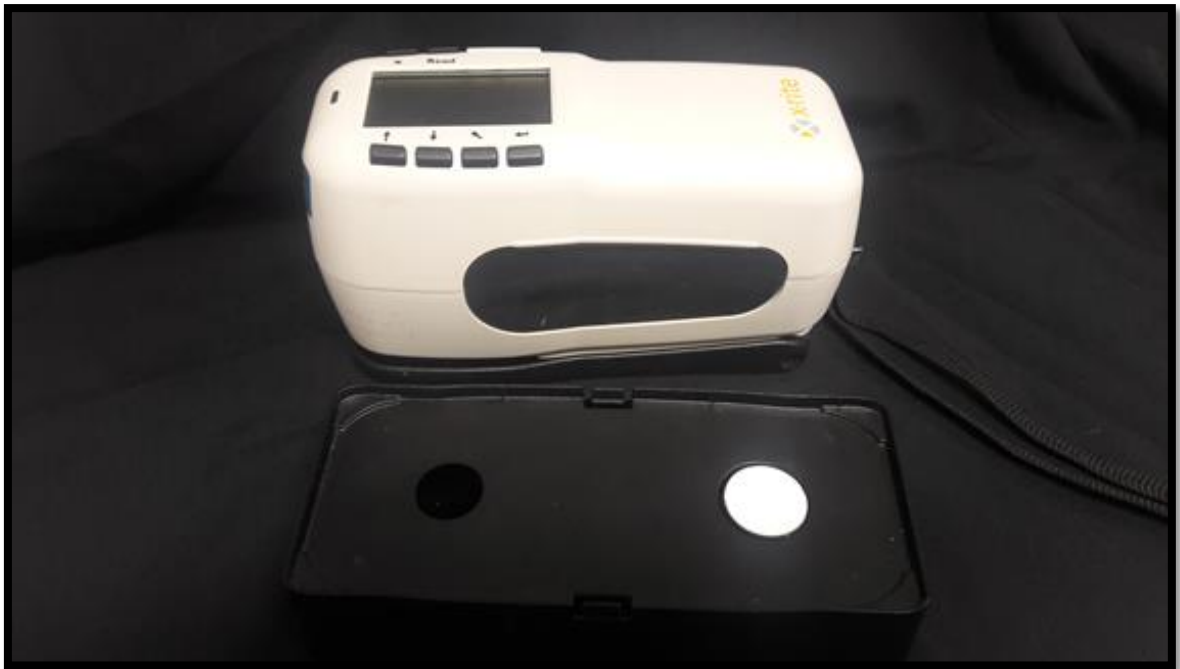


Figura 3 - Espectrofotômetro de esfera (SP60, X-Rite, Grand Rapids, MI, EUA)

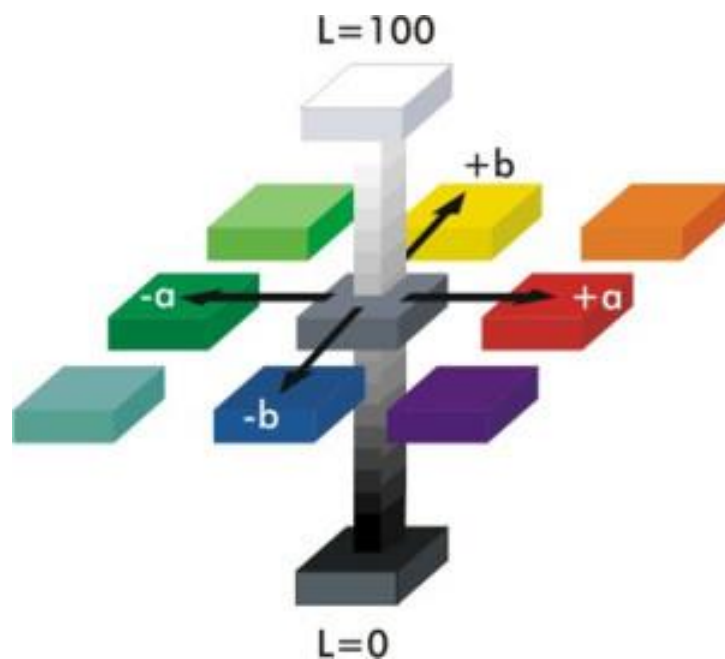


Figura 4 - Sistema de CIE $L^*a^*b^*$

Os corpos-de-prova foram posicionados no foco de um suporte de acrílico transparente, e as medidas foram realizadas com um iluminante D65, no comprimento de onda variando de 400 a 700nm, e com a luz especular incluída (modo SPIN). Devido à geometria da

esfera do espectrofotômetro, o objeto foi iluminado difusamente e o detector recebeu a luz refletida em um ângulo de 8° a partir da superfície do corpo-de-prova. Os parâmetros de cor foram medidos sobre fundo um branco ($L = 95,2$; $a = -1,2$; $b = 0,3$) e preto ($L = 0,2$; $a = 0,3$, $b = 0,2$), enquanto a opacidade foi calculada automaticamente por espectrofotômetro por diferença entre as cores medidas usando esses dois fundos. A média de opacidade e o intervalo de confiança a 95% foram calculados para cada compósito.

Em seguida, três outros corpos-de-prova cilíndricos (10 mm de diâmetro x 3,0 mm de espessura) foram confeccionados para cada compósito de cor correspondente à dentina. Combinando estes cilindros com os de esmalte confeccionados previamente (1 mm de espessura) resultou em nove pares de cilindros de esmalte-dentina por sistema de resina composta ($n = 9$). Para mensuração de cor, o cilindro de resina de esmalte foi posicionado sobre o correspondente de cor de dentina com uma fina camada de glicerol interposta entre eles para evitar alterações significativas do índice de refração causado pelo ar (Figura 5); e os pares de cilindros de esmalte-dentina combinados foram colocados sobre um fundo escuro, usado para mimetizar fundo escuro da cavidade bucal ($L = 24,7$, $a = 0,1$, $b = 0,1$). A calibração do equipamento foi realizada imediatamente antes da série de medições usando uma plataforma branca fornecida pelo fabricante. As mensurações de cor foram feitas em triplicata e as médias desses valores foram usadas para calcular os padrões de cor para cada sistema de compósito. A opacidade dos cilindros de resina de dentina, isoladamente e combinada, com cilindros de resina de esmalte também foi avaliada usando o mesmo protocolo descrito anteriormente.

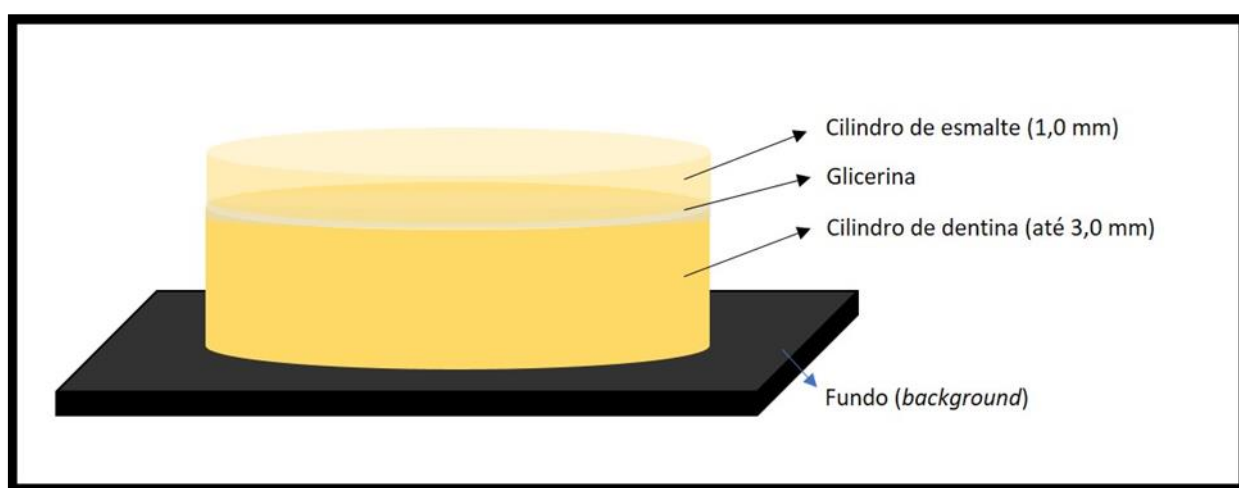


Figura 5 - Ilustração esquemática do posicionamento dos cilindros de resina para mensuração de cor.

Para definir o efeito da redução das espessuras dos corpos-de-prova de cor de dentina na cor final, estes foram desgastados em intervalos de 0,1 mm de espessura com papel de SiC de granulação nº 600 até alcançar 1,0 mm de espessura. A cor dos cilindros combinados (1,0 mm de espessura de esmalte e cilindro desgastado da cor da dentina) foram medidas a cada desgaste de acordo com a descrição anterior. Com base nas alterações nos parâmetros de cor, a mudança de cor do conjunto (ΔE_{00}) em relação ao uso de cilindro de dentina de 3,0 mm foi calculada de acordo com uma fórmula abaixo (15). Para cada espessura de dentina, a opacidade deste cilindro era mensurada isoladamente ou em combinação com os cilindros correspondentes de esmalte.

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L}{KLSI}\right)^2 + \left(\frac{\Delta C}{KcSc}\right)^2 + \left(\frac{\Delta H}{KhSh}\right)^2 + Rt * \left(\frac{\Delta C}{KcSc}\right) * \left(\frac{\Delta H}{KhSh}\right)}$$

Os dados de ΔE_{00} (média e erro padrão) foram plotados em função da espessura da cor da dentina de cada sistema composto, seguido pelo cálculo de regressões polinomiais na 3ª ordem. As fórmulas dessas regressões polinomiais foram usadas para estimar a redução mínima na espessura do cilindro composto de resina dentinária necessária para obter mudanças de cor perceptíveis e clinicamente relevantes. Os valores de ΔE_{00} relatados por um estudo anterior (16) como os valores limiares indicando mudanças de cores perceptíveis e clinicamente aceitáveis foram usados. Além disso, os intervalos de confiança a 95% para cada espessura mínima do compósito da cor da dentina foram calculados com base nos erros padrão de ΔE_{00} obtidos no presente estudo. Gráficos de ΔE_{00} como função das mudanças de opacidade dos pares de cilindros de resina dentinária e esmalte-dentina foram também plotados. Regressões lineares para cada conjunto de dados foram calculadas. Todas as análises de dados e plotagem gráfica foram realizadas utilizando o software estatístico SigmaPlot 12.0 (Systat Software Inc., Chicago, IL, EUA) e o nível de significância foi estabelecido em 95%.

4 RESULTADOS

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PERCEPTIBILITY AND ACCEPTABILITY THRESHOLDS OF COLOR CHANGES CAUSED BY REDUCTION ON DENTIN SHADE COMPOSITE THICKNESS

Short title: Color changes by thin dentin shade composite

Sheila Mara Moraes Santos – Graduate Programa in Dentistry, Federal University of Sergipe, Aracaju, Sergipe, Brazil.

Paula Damasceno Silva - Graduate Programa in Dentistry, Federal University of Sergipe, Aracaju, Sergipe, Brazil.

André Luis Faria-e-Silva - Department of Dentistry, Federal University of Sergipe, Aracaju, Sergipe, Brazil.

*Corresponding author:

Prof. Dr. André Luis Faria-e-Silva; Programa de Pós-Graduação em Odontologia, Rua Cláudio Batista, s/n, Sanatório, Aracaju, SE, Brazil. CEP 49060-100. Telephone: +55 79 3194-7220. E-mail: fariaesilva.andre@gmail.com

Summary

This study aimed to determine the reduction threshold on thickness of dentin shade composite necessary to result in perceptible and acceptable color changes on simulated restorations. Three composite systems (Charisma Diamond, IPS Empress Direct, and Filtek Z350 XT) were evaluated using cylinder-shaped specimens built-up with dentin and enamel shades. Opacity of the composites was assessed using 1.0 mm thick specimens over black and white backgrounds. A baseline color was established for each system by combining 1.0 mm thick enamel shade with 3.0 mm of dentin shade cylinders over a dark background ($n = 9$). Then, the color changes (ΔE_{00}) caused by sequential 0.1 mm reductions on dentin shade cylinders were calculated. Opacity changes on dentin shade cylinders and combined enamel-dentin pair cylinders were also assessed after each thickness reduction. Polynomial regression was performed with averages of ΔE_{00} as function of thickness of dentin shade cylinders; and acceptability ($\Delta E = 1.77$) and perceptibility ($\Delta E = 0.81$) thresholds were calculated. Linear regressions were also performed for ΔE_{00} as function of opacity of dentin shade cylinders and combined enamel-dentin pair of cylinders. Except for Charisma, enamel shades presented lowest opacity than dentin one. Perceptible and acceptable color changes were observed for dentin shade cylinders thinner than 2.0-2.4 mm and 1.1-1.4 mm, respectively, were used. No difference among the composite systems were observed. In conclusion, reductions of dentin shade composite lower than 0.6-mm and 1.6-mm did not result in perceptible and clinically relevant changes, respectively, on ultimate color of simulated restorations.

Keywords: Color; Composite dental resin; Esthetics, Dental; Optical phenomena.

INTRODUCTION

Direct composite restorations in anterior teeth has been demonstrated be an excellent option to solve esthetic concerns involving alteration in color and/or shape of teeth, or to close diastemata (1-3). Further to easy handling characteristics, the composite systems available nowadays present several shades allowing to mimic both enamel and dentinal tissues (4-5). When compared to ceramic veneers, composite resin presents reduced cost that allows its indication for patients with reduced willingness to pay (6). However, the ability and knowledge of clinicians regarding esthetic aspects of smile, and optics characteristics of hard tooth tissue and composites are essential to achieve esthetical direct restorations.

Enamel is a crystalline tissue characterized by high mineral content, which results in a chromatic translucent structure that allows to visualize the underlying dentin (5,7,8). Furthermore, the chromaticity of enamel modify the dentin color and affect the ultimate tooth color (5). On the other hand, the higher organic content of dentin increases its opacity and the chromaticity of this tissue strongly affects the tooth color (8). Similarly, composites shades are available in different degrees of translucency seeking out to simulate the optical characteristics of enamel and dentin (3,5). Further to translucency degree, the thickness of composite increment also affects the light transmission through the material bulk (9,11). Therefore, using the same thickness of hard tooth tissue only would result in similar optical aspects if the translucency/ opacity of the composite was like those observed from dentin and enamel. However, composites with different degrees of translucency/ opacity are available in the market. An important matter hindering the stratification of composite restoration is that the enamel shade composites of some manufacturer are more translucent than the tooth enamel, while some dentin shade composites are opaquer than tooth dentin (12,13).

In some clinical situations, the knowledge of opacity features of materials further to their color is essential to obtain esthetic restorations. Opaquer composites are required to mask any dentin discoloration, such as sclerotic dentin, or avoid visualizing the oral cavity beneath the restoration, while this last occurrence can gray out the restoration color (9,14). The composite ability to mask any dark background also depends on its thickness and the placement of opaquer composite in layers thinner than required can affect the ultimate color of restoration. Therefore, this study aimed to determine the thresholds of thickness reduction on dentin shade composites necessary to cause perceptible and clinically relevant color changes on simulated restorations over a dark background, maintaining constant the thickness of enamel shade composite.

MATERIAL AND METHODS

Three systems of composite resins were evaluated in the present study: Charisma Diamond (Heraeus Kulzer, Hanau, Germany), IPS Empress Direct (Ivoclar Vivadent, Schaan, Liechtenstein), and Filtek Z350 XT (3M ESPE, St. Paul, MN, USA). For each system, two shades with opacities corresponding to enamel and dentin were selected. To characterize the opacity of dentin and enamel shades from each system, cylinder-shaped specimens (10 mm diameter x 1.0 mm thickness) were built-up by insertion of composites into a metallic mold. The composites were light-cured with a LED-based unit Radian Cal (irradiance $\approx 1,000$ mW/cm²; SDI, Victoria, Australia) for 40 s, followed by the specimens polishing with aluminum oxide abrasive disks, and the final diameter was measured with a digital caliper.

The opacity of specimens ($n = 3$) was assessed with a sphere spectrophotometer (SP60, X-Rite, Grand Rapids, MI, USA), in reflectance mode, using CIE $L^*a^*b^*$ system (L^* : white/black; a^* : red/green; b^* : yellow/blue). Specimens were positioned in focus on a clear acrylic stand, and the measurements were performed with a D65 illuminant, in the wavelength ranging from 400 to 700 nm, and with the specular light included (SPIN mode). Due to sphere geometry of spectrophotometer, the object was illuminated diffusely and the detector received the reflected light at an 8° angle from the surface of the composite cylinder. The color parameters were measured over white ($L^* = 95.2$, $a^* = -1.2$, $b^* = 0.3$) and black ($L^* = 0.2$, $a^* = 0.3$, $b^* = 0.2$) backgrounds, while the opacity was automatically calculated by spectrophotometer by difference between the colors measured using these backgrounds. The average of opacity and the confidence interval at 95% were calculated for each composite.

Afterwards, three other cylinder-shaped specimens (10 mm diameter x 3.0 mm thickness) were confectioned for each dentin shade composite. Combining these cylinders with the 1-mm thick enamel shade cylinders from the same brand resulted in nine pairs of enamel-dentin cylinders per composite system ($n = 9$). Then, the enamel shade cylinder was positioned over the dentin shade one with a thin layer of glycerol between them to avoid significant changes of refractive index caused by air; and the combined enamel-dentin shades pairs of cylinders were placed over a dark background ($L^* = 24.7$, $a^* = 0.1$, $b^* = 0.1$). The color of cylinders pairs was measured and the values of L^* , a^* and b^* recorded. Three measurements were performed for each pair and the averages of these values were used to calculate the mean parameters of color for each composite system. This first color assessment using 3-mm thick dentin shade cylinders was defined as the color standard. The opacity of dentin shade cylinders

alone and combined with enamel shade cylinders were also assessed using the same protocol described previously.

Following, the dentin shade cylinders were abraded until reach 2.9 mm of thickness with 600-grit SiC paper. The color and opacity of the combined cylinder (1.0-mm of thickness enamel shade and 2.9-mm of thickness dentin shade) were measured according prior description. Based on changes on color parameters, the pooled color change (ΔE_{00}) was calculated according with the following formula (15):

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L}{KlSl}\right)^2 + \left(\frac{\Delta C}{KcSc}\right)^2 + \left(\frac{\Delta H}{KhSh}\right)^2 + Rt * \left(\frac{\Delta C}{KcSc}\right) * \left(\frac{\Delta H}{KhSh}\right)}$$

The opacities of dentin shade alone and combined with corresponding enamel shade cylinder were also measured. The opacity and color measurements were repeated after each 0.1-mm reduction on dentin shade composite cylinder until using 1.0-mm of thickness dentin shade composite cylinders. Color changes (ΔE_{00}) were calculated after each thickness reduction based on color measured with 3.0-mm thick dentin shade cylinder.

Data of ΔE_{00} (mean and standard error) were plotted as function of dentin shade thickness from each composite system, followed by calculation of polynomial regressions at 3rd order. The formulas of these polynomial regressions were used to estimate the minimum reduction on thickness of dentin shade composite cylinder required to obtain perceptible and clinically relevant color changes. The values of ΔE_{00} reported by a prior study (16) as the threshold values indicating perceptible (0.81) and clinically acceptable (1.77) color changes were used. Further, the confidence intervals at 95% for each minimum thickness of dentin shade composite were calculated based on standard errors of ΔE_{00} obtained in the present study. Graphics of ΔE_{00} as function of opacity changes of dentin shade composite and enamel-dentin pairs of cylinders were also plotted. Linear regressions for each data set were calculated. All data analyses and graphics plotting were performed using the SigmaPlot 12.0 statistical software package (Systat Software Inc., Chicago, IL, USA) and significance level was set at $\alpha = 0.05$.

RESULTS

Table 1 presents the composites evaluated in the present study and their opacity measured with 1.0 mm thick specimens. No significant differences were observed among the dentin shades composites. Regarding the enamel shades, IPS Empress Direct and Filtek Z350 XT presented similar opacities and lower than that measured for Charisma Diamond. For this last composite system, similar opacities were observed between enamel and dentin shades for Charisma Diamond. Enamel shades were more translucent than dentin shade for the other composite systems.

Curves of ΔE_{00} as function of thickness of dentin shade composite are displayed at Figure 1. All regressions presented p-values lower than 0.001; and the determination coefficient ranged from 0.893 (IPS Empress Direct) to 0.955 (Filtek Z350 XT). Table 2 presents the values of minimum thickness reduction of dentin shade cylinders to results in perceptible and clinically acceptable color changes. To obtain perceptible changes from color obtained with 3.0 mm thick dentin cylinders, it was necessary to reduce the dentin shade cylinder until obtain thickness ranging from 2.41 mm (Filtek Z350 XT) to 2.01 mm (IPS Empress Direct). However, no significant difference was observed among the composite systems. Regarding to maintain the color changes clinically acceptable, the dentin shades cylinders couldn't be thinner than 1.44-mm, 1.30-mm and 1.15-mm for Filtek Z350-XT, IPS Empress Direct and Charisma Diamond, respectively. No significant statistical difference among the composites systems was also observed regarding the thickness of dentin shade cylinders required to maintain the color change clinically acceptable.

Linear regressions of ΔE_{00} as function of opacity of dentin shade cylinders and enamel-dentin shades pairs cylinders are illustrated at Figure 2 and 3, respectively. Determinant coefficients were higher using data of the dentin shade cylinders (ranged from 0.707 to 0.932) than correlating with opacity of the enamel-dentin shades pairs cylinders (ranged from 0.524 to 0.716). All linear regressions presented p-value lower than 0.001.

DISCUSSION

Despite the reduced cost and adequate clinical behavior, obtaining aesthetic direct restorations with composites remains a challenge for the clinicians since to reproduce the optical features of hard dental tissues can be a difficult task (3-5, 9, 17-19). Moreover, resin-based materials with different optical features are now available in the market requiring

changes in the restorative approaches according to the material chosen (12-14). Further to color of the composites, the opacity of the material also strongly affects the ultimate color of restoration, mainly when discolored substrates are underlying the restoration or incisal areas are restored (9). In this last case, any visualization of the dark oral cavity through the restorative material presenting improper level of translucency results in grayer (reduced lightness) restoration and can compromise the final aesthetic. In the present study, a dark background was used to simulate this clinical situation and only the thickness of the dentin shade was modified.

It has been reported that the enamel thickness significantly affects the ultimate color of tooth structure (8), and so is the enamel shade composite on restoration color (5). In the present study, we choose to maintain the thickness of enamel shade in 1.0 mm for all experimental set-ups since this is the average of human enamel thickness, which varies depends on the type of tooth and anatomical location (21). Using this standard thickness, the opacity of enamel shade composites ranged from 53.7 % for IPS Empress Direct (more translucent) to 62.1 % for Charisma Diamond (opaquer). Regarding the initial dentin shade thickness, we choose to start with 3.0 mm seeking out to completely hide the dark background. However, combining 1.0 mm thick enamel shade and 3.0 mm thick dentin shade allowed some light transmission and slight visualization of the dark background (the opacity ranged from 91.7 % for IPS Empress Direct to 94.8% for Charisma Diamond). Indeed, no significant difference between the composite brands in the opacity of dentin shades were observed either for cylinders with 1.0 mm (61.1 to 64.8 %) or 3.0 mm (88.2 to 88.5 %) of thickness; and the opacities of enamel-dentin shade combination were strongly affected by the enamel shade opacity.

Therefore, based only in the enamel shades opacities, it could be expected that reducing the dentin shade thickness would result in more pronounced changes in ΔE_{00} for the restorative systems presenting more translucent enamel shades. In fact, the correlation tests showed the lowest slope of lines (demonstrated by linear regression) for Charisma Diamond (opaquer enamel shade) for either correlations between ΔE_{00} and the opacity of the dentin shade cylinders (3.41) or the enamel-dentin pairs of cylinders (6.17). IPS Empress direct and Filtek Z350 XT present more translucent enamel shade composites (53.7 and 56.4, respectively), resulting in increased slope in lines of correlations between ΔE_{00} and the opacity of the dentin shade cylinders (7.08 and 6.02, respectively) or the enamel-dentin pairs of cylinders (11.59 and 12.37, respectively). Interestingly, the determination coefficients were higher for linear regressions with data of dentin shade cylinders opacity than those of enamel-dentin pairs; suggesting that the changes in dentin shade opacity affected more the ultimate color than the

changes in overall opacity of specimens. However, these findings are explained due to maintaining the thickness of enamel shade cylinders constant during the measurements and any change in the overall opacity was due to reductions in opacity of the dentin cylinders.

Changes on dentin shade cylinders opacity were performed by abrasion of the cylinders to obtain sequential 0.1 mm reductions on their thickness until to evaluate the 1.0 mm thick dentin shade specimens. Thinner cylinders were not used in the experiment due to difficulty to control the abrasion procedures of thin specimens. Therefore, polynomial regressions were performed to estimate the ΔE_{00} for using dentin shade cylinders with intermediate thicknesses or thinner than 1.0 mm. These regression analyses presented high determination coefficients (ranging from 0.894 to 0.955) demonstrating the formulas calculated strongly explain the relation between the thickness of dentin shade composites and changes on the ultimate color. Based on these formulas, the thicknesses of dentin shade cylinders required to yield perceptible and clinically relevant color changes were calculated. Data of ΔE_{00} from a prior study that calculated the color change thresholds required to 50% of observers consider the difference of color between two objects as visually perceptible or clinically acceptable were used (16). The results of present study did not demonstrate any significant difference among the composite brands analyzed. Reductions of 0.59 to 0.99 mm in dentin shade cylinders were necessary to yield perceptible color changes; while only reductions higher than 1.56-1.85 mm in dentin shade cylinders resulted in color changes clinically unacceptable. Therefore, for the composites evaluated in the present study, the placement of dentin shade composites thicker than 1.15-1.44 mm seems does not modify significantly the ultimate color of restorations when a 1.0 mm thick enamel shade composite is also used.

In the present study, the composite A1B was used as dentin shade for the system Filtek Z350 XT because this shade presents opacity closer than that observed for human dentin than the opaquer composite A1D from the same manufacturer.¹² Regarding the Charisma Diamond, this composite system presents four shades indicated to be used as dentin shades: OL (lighter), OM (medium), OD (darker), and OB, which is indicated for bleached tooth. Therefore, we choose to evaluate the shade OL that is closer shade to A1 used for the other composites. In conclusion, the results of present study demonstrated that, despite differences on opacity among the composite systems evaluated, similar thickness reductions were necessary to cause perceptible and clinically relevant color changes. However, it is important to emphasize that only lighter composites were evaluated in the present study and the findings cannot be extrapolated for other shades since the opacity also depends on the composite shade (21).

SUMMARY IN PORTUGUESE

Este estudo objetivou determinar o limiar de redução na espessura do compósito de cor da dentina necessário para resultar em mudanças de cor perceptíveis e aceitáveis em restaurações simuladas. Três sistemas de compósitos (Charisma Diamond, IPS Empress Direct e Filtek Z350 XT) foram avaliados utilizando corpos-de-prova cilíndricos construídos com cores de dentina e esmalte. A opacidade dos compósitos foi avaliada usando cilindros de 1,0 mm de espessura sobre fundo preto e branco. Uma cor inicial padrão foi estabelecida para cada sistema pela combinação de esmalte de 1,0 mm de espessura com 3,0 mm de cilindros de resina na cor de dentina sobre um fundo escuro ($n = 9$). Em seguida, foram calculadas as alterações de cor (ΔE_{00}) causadas por reduções sequenciais de 0,1 mm nos cilindros de resina na cor de dentina. Mudanças de opacidade em cilindros na cor de dentina e cilindros combinados de esmalte e dentina foram também avaliadas após cada redução de espessura. Regressão polinomial foi realizada com médias de ΔE_{00} em função da espessura dos cilindros na cor de dentina; e os limiares de aceitabilidade ($\Delta E_{00} = 1.77$) e perceptibilidade ($\Delta E_{00} = 0.81$) foram calculados. Regressões lineares também foram realizadas para ΔE_{00} em função da opacidade dos cilindros na cor de dentina e do par combinado de cilindros de esmalte-dentina. Com exceção da Charisma, os compósitos de esmalte apresentaram menor opacidade do que os de dentina. Alterações de cor perceptíveis e aceitáveis foram observadas quando os cilindros na cor de dentina foram mais finos que 2,0-2,4 mm e 1,1-1,4 mm, respectivamente. Nenhuma diferença entre os sistemas compostos foi observada. Em conclusão, as reduções do compósito da cor da dentina inferiores a 0,6 mm e 1,6 mm não resultaram em alterações perceptíveis e clinicamente relevantes, respectivamente, na cor final das restaurações simuladas.

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Table 1. Description of composites systems and their shades used in the present study and the means of opacity (95% confidence interval) measured using 1.0-mm thick disks.

Composite system	Manufacturer	Shades	Opacity
Charisma Diamond	Heraeus Kulzer, Hanau, Germany	A1 (enamel)	62.1 (60.2/ 64.0)
		OL (dentin)	64.4 (62.9/ 65.8)
IPS Empress Direct	Ivoclar Vivadent, Schaan, Liechtenstein	EA1 (enamel)	53.7 (51.7/ 55.8)
		DA1 (dentin)	64.8 (63.4/ 66.2)
Filtek Z350 XT	3M ESPE, St. Paul, MN, USA	A1E (enamel)	56.4 (54.9/ 57.8)
		A1B (dentin)	61.1 (58.7/ 63.6)

Table 2. Estimated values (95% confidence intervals*) of composite thickness corresponding to dentin shade required to not affect the perceptibility and acceptability of ultimate color measured with dentin shade (3.0 mm of thick at baseline) under 1-mm thick enamel shade over black background.

Composite system	Parameter**	
	Perceptibility	Acceptability
Charisma Diamond	2.20 (1.87 – 2.51)	1.15 (0.97 – 1.67)
IPS Empress Direct	2.01 (1.81 – 2.27)	1.30 (1.09 – 1.49)
Filtek Z350 XT	2.41 (2.16 – 2.71)	1.44 (1.16 – 1.73)

* Estimated using the variation coefficient of ΔE_{00} values.

**Values of 50:50% color changes threshold determined by Paravina et al. 2015 – (ΔE_{00} for perceptibility = 0.81; ΔE_{00} for acceptability = 1.77).

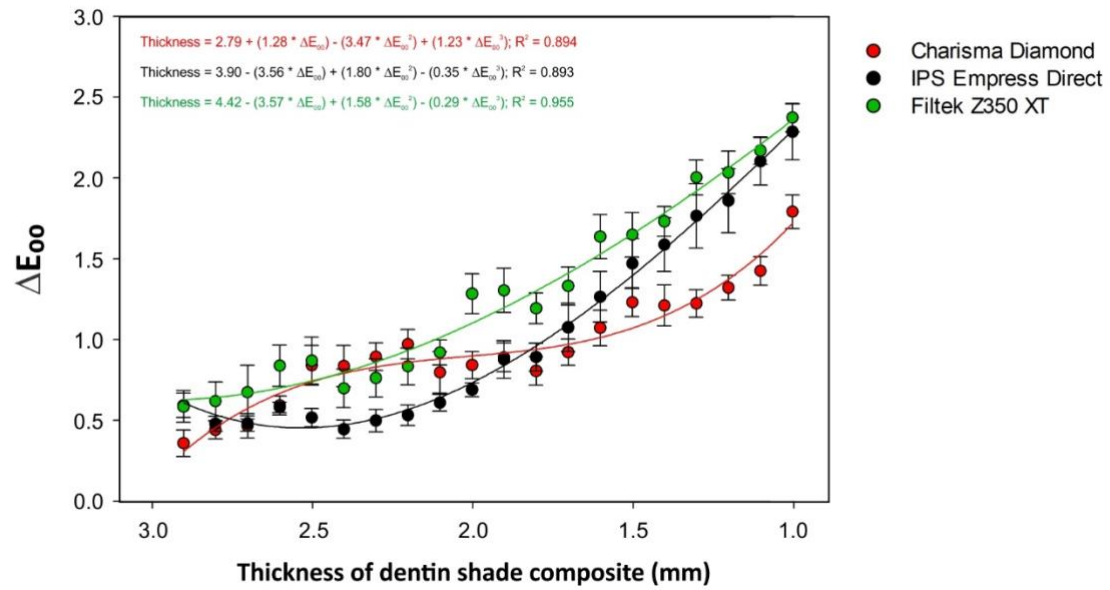


Figure 1. Behavior of data (average; standard error) of ΔE_{00} as function of thickness of dentin shade composite measured for different composite systems. The lines represent the results of polynomial regression (3rd order) for each composite. The formulas polynomial regression (3rd order) and determination coefficients (R^2) are described in the figure. Red line and formula – Charisma diamond; Black line and formula – IPS Empress Direct; Green line and formula – Filtek Z350 XT.

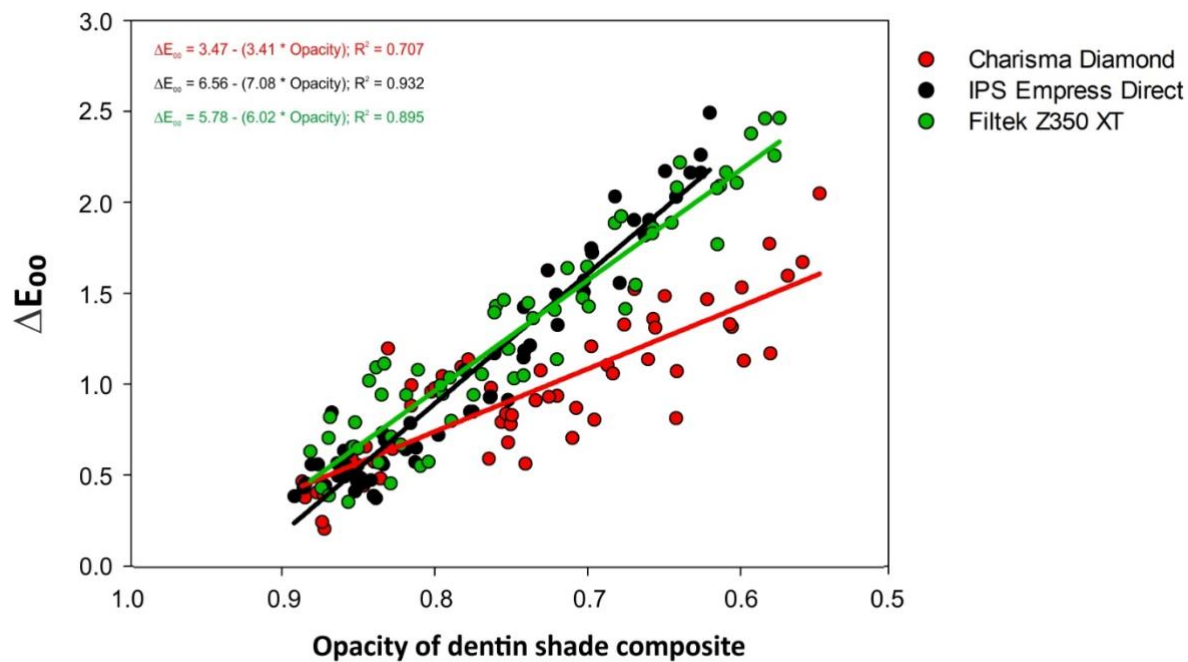


Figure 2. Behavior of data of ΔE_{00} as function of opacity of dentin shade composite measured for different composite systems. The lines represent the results of linear regression for each composite. The formulas linear regression and determination coefficients (R^2) are described in the figure. Red line and formula – Charisma diamond; Black line and formula – IPS Empress Direct; Green line and formula – Filtek Z350 XT.

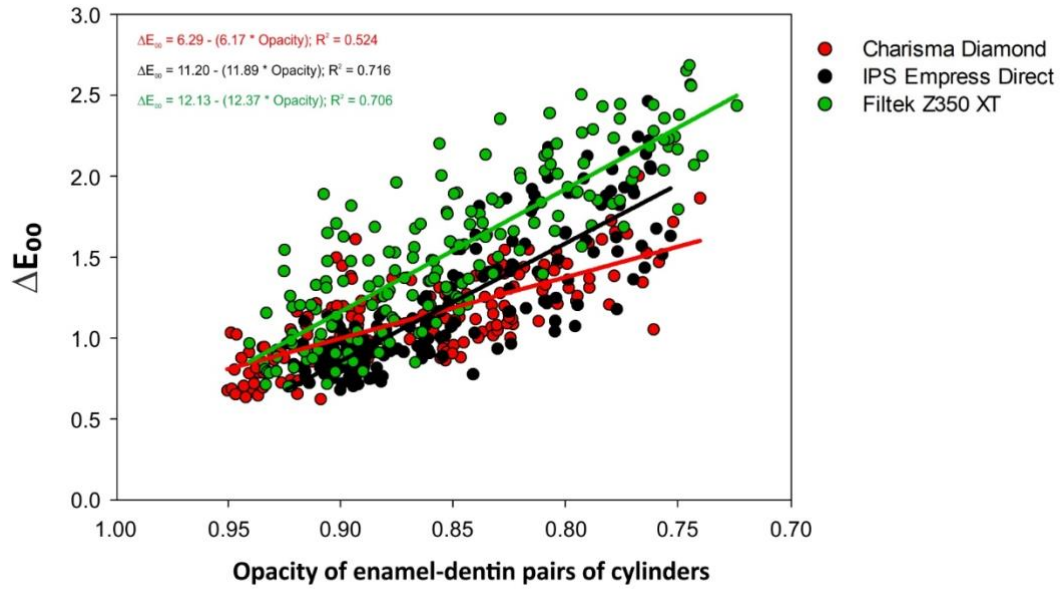


Figure 3. Behavior of data of ΔE_{00} as function of opacity of specimens (dentin shade disks over 1.0-mm thick enamel shade disks) measured for different composite systems. The lines represent the results of linear regression for each composite. The formulas linear regression and determination coefficients (R^2) are described in the figure. Red line and formula – Charisma diamond; Black line and formula – IPS Empress Direct; Green line and formula – Filtek Z350 XT.

5 CONSIDERAÇÕES FINAIS

Os resultados do presente estudo demonstraram que, apesar das diferenças na opacidade entre os sistemas de compósitos avaliados, reduções de espessura semelhantes foram necessárias para causar alterações de cor perceptíveis e clinicamente relevantes. Entretanto, é importante ressaltar que apenas compósitos mais claros foram avaliados no presente estudo e os achados não podem ser extrapolados para outras cores, uma vez que a opacidade também depende da cor do compósito.

6 COMUNICADO DE IMPRENSA

Durante um tratamento restaurador estético, o cirurgião-dentista busca mimetizar as estruturas duras de dente, denominadas de esmalte e da dentina, de forma a “esconder” a restauração. Para isso, os fabricantes de resina composta disponibilizam resinas que simulam tanto a cor quanto a opacidade, que é inabilidade de permitir a passagem de luz, dos tecidos dentais. Entretanto, a espessura em que o dentista insere a resina na cavidade também afeta o resultado final da restauração, desde que menores espessuras permitem maior passagem de luz e podem deixar transparecer uma estrutura dental adjacente mais escura ou o fundo da cavidade oral, o que deixaria a restauração mais cinza. Assim, o uso de uma espessura adequada da resina correspondente à dentina, mais opaca, é fundamental para obter boa estética e esconder um dente manchado/ escurecido ou para não deixar a restauração acinzentada. Assim, uma dissertação desenvolvida pela cirurgiã-dentista Sheila Mara Morais Santos, no Programa de Pós-Graduação em Odontologia da Universidade Federal de Sergipe, sob orientação do Prof. Dr. André Luis Faria e Silva, buscou determinar as espessuras mínimas de resina na cor de dentina, para três marcas comerciais, que devem ser usadas para evitar alterações de cor perceptíveis ou clinicamente relevantes em restaurações. Os resultados do estudo demonstraram que espessuras similares são necessárias entre as marcas de resina avaliadas. Espessuras entre 2,0 e 2,4 mm são necessárias para evitar que uma cor escura, equivalente ao fundo da cavidade oral, afete da cor final da restauração de forma perceptível aos olhos humanos. Entretanto, apenas espessuras menores que 1-1,4 mm causam alterações clinicamente relevantes na cor final de restauração.

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